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BUFFALO LAKE PROJECT, RANDALL COUNTY, TEXAS. RESULTS OF A COOPERATIVE WATER QUALITY SURVEY WITH THE TEXAS WATER QUALITY BOARD OF BUFFALO LAKE AND ITS TRIBUTARIES, TIERRA BLANCA CREEK AND FRIO DRAW

Robert A. Kerr Water Research Center
Ada, Oklahoma

December 1968

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BUFFALO LAKE PROJECT
RANDALL COUNTY, TEXAS

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ROBERT S. KERR WATER RESEARCH CENTER
TECHNICAL ASSISTANCE PROGRAM
ADA, OKLAHOMA

DECEMBER, 1968

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BUFFALO LAKE PROJECT
RANDALL COUNTY, TEXAS

Results of a cooperative water quality survey with the Texas Water Quality Board of Buffalo Lake and its tributaries, Tierra Blanca Creek and Frio Draw.

U. S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
ROBERT S. KERR WATER RESEARCH CENTER
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ADA, OKLAHOMA

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BUFFALO LAKE TECHNICAL ASSISTANCE PROJECT

INTRODUCTION

Buffalo Lake is a shallow, man-made reservoir of 18,150 acre-feet capacity located on Tierra Blanca Creek, some 50 miles southwest of Amarillo, Texas. During this study the lake was only 13 feet deep at its deepest portion near the dam. At this depth the lake contained 3,990 acre-feet of water and had a surface area of approximately 950 acres. The shoreline is characterized by gently sloping sandy beaches readily accessible by automobile.

The U. S. Fish and Wildlife Service operates Buffalo Lake as a National Wildlife Refuge and public recreation area with an estimated 20,000 persons having visited the Refuge over a peak holiday weekend period. The location of Buffalo Lake on the high plains of the Texas Panhandle provides one of the few water orientated recreation sites in this relatively dry area.

Fish kills have occurred in Buffalo Lake, Texas, and along Tierra Blanca Creek on June 15, 1964, and again on June 16, 1967. [5,14] After the 1967 fish kill, bacteriological analyses indicated that Buffalo Lake was severely contaminated with bacteria of fecal origin. [25,26] These results caused the lake to be posted to water contact sports from June 28, 1968, to July 18, 1968.

The posting of Buffalo Lake in 1967 caused the cancellation of two national water skiing regattas scheduled for the lake. The holding of these two regattas would have added $128,000 to the economy of the area, and would have afforded additional recreational opportunities

valued at $40,000. Because of the lake's importance to the people of the high plains area, all local news media have had broad coverage of the pollution problems affecting Buffalo Lake.

Request and Authority

The Texas Water Quality Board, in a letter dated January 2, 1968, requested the assistance of the Federal Water Pollution Control Administration in determining the cause of the fish kills and the source of the fecal bacteria in Buffalo Lake, so that control of the responsible waste discharges might be achieved. [34/] Section 5 of the Federal Water Pollution Control Act, as amended (33 U.S.C. 466 (5), authorizes the Secretary of the Interior to conduct such investigations. [29/]

Scope

Bacteriological studies, together with some chemical analyses and engineering evaluations, constituted FWPCA's contribution to the Buffalo Lake study. The Texas Water Quality Board is in charge of the overall study and has the responsibility for most aspects of the study. This report, as prepared by the Technical Assistance Program of the Robert S. Kerr Water Research Center, is concerned primarily with the interpretations and recommendations related to the bacteriological studies. A final report for the entire Buffalo Lake study will be prepared by the Texas Water Quality Board.

The area covered by this study is the area draining to Buffalo Lake along Tierra Blanca Creek and its tributary, Frio Draw. Figure 2 at the back of this report shows the study area and its pertinent features. Tierra Blanca Creek originates in New Mexico and is the headwater tributary of Prairie Dog Town Fork of the Red River. Frio

Draw, Tierra Blanca Creek, and Buffalo Lake are all interstate waters and the pertinent water quality standards adopted by Texas and approved by the Secretary of the Interior are applicable.

Objectives

The overall objective of the Buffalo Lake pollution study as sponsored by the Texas Water Quality Board is to determine the cause of the recurring pollution of Buffalo Lake. The Texas study will assess the quantity and quality of pollutants discharged by each major waste source and the effect these wastes have on the water quality of the receiving stream and Buffalo Lake.

The objectives to be accomplished by the Technical Assistance Program of the Robert S. Kerr Water Research Center in regard to the Buffalo Lake study are obtaining answers to the following questions:

1. What effect do the various waste sources have on the bacteriological quality of the receiving stream and Buffalo Lake?
2. What is the fate of the three indicator groups of bacteria (total coliform, fecal coliform, and fecal streptococci) entering Buffalo Lake?
3. What effect does the extensive water contact recreational use of Buffalo Lake have on the total coliform, fecal coliform, and fecal streptococci densities?
4. What are the densities of coliform, fecal coliform, and fecal streptococci in Buffalo Lake and along Tierra Blanca Creek and Frio Draw before and after a rainfall period?

5. Does the bottom mud in Buffalo Lake contain any appreciable densities of the three bacterial indicators?
6. Do any appreciable concentrations of pesticides exist in Buffalo Lake or enter the lake due to surface runoff?
7. What corrective measures should be taken to control the bacterial pollution of Buffalo Lake and its tributaries?

Acknowledgments

The assistance of many people and several agencies is gratefully acknowledged. The Refuge Manager of Buffalo Lake National Wildlife Refuge was especially generous in lending boats and personnel to aid in the survey. Personnel from the Texas Water Quality Board, Texas State Department of Health, and the Texas Parks and Wildlife Department also helped conduct the field survey. A list of the people participating in the FWPCA's portion of the study is shown in Appendix C.

SUMMARY

1. The possible sources of pollution along Tierra Blanca Creek and Frio Draw include cattle feedlots, slaughter houses, a beet sugar refinery, vegetable processing plants, and municipal waste treatment plants. Uncontrolled runoff from the cattle feedlots has been cited in previous reports as being a logical source of the pollution entering Buffalo Lake. Preliminary investigations revealed that the sugar refinery retains all of its waste effluent in ponds and then uses this water for irrigation.

2. The recorded fish kills at Buffalo Lake have occurred during periods of heavy rainfall and subsequent runoff. At Hereford, Texas, where the major concentration of feedlots is located, the mean annual rainfall is 19 inches. Up to one-third of this rainfall occurs during heavy thunderstorm activity in May and June.

3. The sampling program arranged by the Texas Water Quality Board incorporated taking monthly samples at six points along Tierra Blanca Creek, one point on Frio Draw, and six locations on Buffalo Lake. During a period of runoff, an additional eight points on Tierra Blanca Creek and four locations on Frio Draw were sampled. An additional three locations in Buffalo Lake, two on Frio Draw, and one on Tierra Blanca Creek were sampled at least once for special purposes during the recreation and runoff portions of the study.

4. A four-phase plan was developed to answer the questions posed in the Project Objectives. The objective of Phase I was to acquire some background bacteriological data for all sample stations.

In Phase II the two primary objectives were to acquire additional background bacteriological data, and to note the effect of recreational use on the bacteriological quality of Buffalo Lake. Phase III was dependent upon adequate rainfall, so that the effect of runoff on the receiving stream and Buffalo Lake could be noted. Data analyses and preparation of this report was carried out in Phase IV.

5. Phase I was initiated by the movement of a mobile laboratory properly equipped for bacteriological analyses to Buffalo Lake on April 22, 1968. Samples were analyzed in this laboratory for total coliform, fecal coliform, and fecal streptococci by research microbiologists from the FWPCA's Robert S. Kerr Water Research Center. All 25 sampling stations exhibiting flow were sampled on April 29 and 30, 1968, thus completing Phase I.

6. Phase II was initiated by taking stream and lake samples on June 12 and 13, 1968. Sampling of Buffalo Lake was continued over the weekend (June 15 and 16) and completed on June 17, 1968. Unusual activities in Phase II included sampling stations 6 and 8 at four-hour intervals for 24 hours and continuation of the lake's bottom mud sampling.

7. After several near misses, Phase III was initiated on July 8, 1968, after the extent of precipitation occurring on Sunday, July 7, was ascertained. Additional rains occurred during the early morning hours of July 12 and 13 and special efforts were made to sample the runoff resulting from the rain on the 12th. Sampling continued each day through July 15, 1968.

8. Phase IV for evaluation of data and writing and reviewing the report was begun in August 1968 and terminated with this report.

CONCLUSIONS

1. The bacteriological quality of Tierra Blanca Creek was adversely affected by the large numbers of bacteria discharged in the City of Hereford's treated sewage. Under normal dry weather conditions, total coliform counts of 2.5 million per 100 ml with fecal coliform to fecal streptococci ratios (FC/FS) of seven were found at station 3 just below Hereford's waste effluent.

2. A rather inhospitable environment is afforded the indicator bacteria by Tierra Blanca Creek as evidenced by the rapid die-off of the bacteria in the short distance (0.71 miles) between stations 3 and 4. The fecal coliform die-off was ten times more rapid than the fecal streptococci die-off, resulting in a switch of the FC/FS ratio from 7.0 at station 3 to 0.7 or less at station 4.

3. This study bore out that a FC/FS ratio of 4.0 or more is indicative of domestic sewage.

4. The high counts of fecal bacteria found in Tierra Blanca Creek and Frio Draw during dry weather are indicative of recent fecal pollution from both man and animal sources.

5. In Phase II there was a decrease from Phase I in the counts obtained for all three bacterial parameters at stations 3 and 4 and an increase for all parameters at station 6. The use of a makeshift chlorinator temporarily installed by the City of Hereford at the sewage treatment plant early in June may have influenced the counts at stations 3 and 4 during Phase II.

6. The waters of Buffalo Lake during Phase I were of excellent

bacteriological quality. Total coliform densities found in the lake, with the exception of station 12, were less than 20/100 ml, and fecal coliforms were less than 5/100 ml.

7. When the total coliform counts obtained each day from Buffalo Lake during Phase II were compared one day to another, no statistically significant difference in the daily counts was noted. The daily sampling was conducted over a weekend period during which the number of people participating in water contact recreation was 7,832. This represents an increase of over 600 percent from the previous average weekday. Water contact recreation during the weekend sampled (June 15-16, 1968) did not cause a notable increase in any one day's total coliform count.

8. In Phase II there was a significant increase from Phase I in the densities within all three bacterial parameters at each lake sampling station. In phase II, total coliform counts of 100/100 ml or more were found in several lake samples. These increases may have been due to the higher water temperature and the increased refuge utilization in Phase II; however, the data are not extensive enough to form any definite conclusions.

9. The recreational use patterns of Buffalo Lake appeared to cause the sampling stations nearest the dam (7,8,&8A) to have significantly higher counts of all three bacterial parameters than the other three lake stations. Although water contact recreation did not increase the total coliform concentrations over a weekend period, recreational use does influence the concentration of indicator bacteria at individual stations.

10. The waters of Buffalo Lake during Phase II were still of satisfactory bacteriological quality for water contact recreation.

11. No diurnal variation in the three bacterial parameters was found at stations 6 and 8.

12. Runoff entering Buffalo Lake on June 4, 1968, only amounted to 30 acre-feet, and did not adversely affect the bacteriological quality of Buffalo Lake.

13. Mud samples collected from the lake during Phases I and II did not reveal appreciable densities within the three bacterial parameters. The bottom mud of Buffalo Lake does not appear to contain a sufficient concentration of the three bacterial indicators to cause any bacteriological quality problems in the overlying waters of the lake.

14. At the two times of sampling, no significant pesticides were detected in the mud or waters of Frio Draw, Tierra Blanca Creek, or Buffalo Lake.

15. Runoff waters entering Buffalo Lake on July 8, 1968, contained high densities of all three bacterial indicators. These runoff waters caused the upper end of Buffalo Lake to be contaminated with bacteria of fecal origin. The runoff was not sufficient to contaminate the main water use portion of the lake.

16. Die-off due to environmental factors, including settling and dilution, rapidly decreased the densities of indicator bacteria in the lake's upper end.

17. Additional rain during the early morning hours of July 12 and again on July 13, 1968, provided an opportunity to sample the

runoff from several cattle feedlots. The runoff from these feedlots was grossly polluted with all three bacterial groups. These runoff waters greatly increased the indicator bacteria content of Tierra Blanca Creek and Frio Draw.

18. Dikes to hold back polluted runoff waters and prevent their entrance into the surface streams are an effective, though imperfect, means of preventing water pollution.

19. Surface runoff is the major source of fecal bacteria in Buffalo Lake. Uncontrolled surface drainage from large cattle feedlots contributes large quantities of all three bacterial groups to the waters of Tierra Blanca Creek and Frio Draw.

RECOMMENDATIONS

1. The City of Hereford should properly chlorinate its treated sewage effluent on a continuous basis to protect the bacteriological quality of Tierra Blanca Creek.

2. Adequate facilities to retain surface runoff should be properly constructed for every cattle feedlot to prevent the feedlot's drainage from entering the surface stream.

3. Each time any quantity of surface runoff enters Buffalo Lake, the bacteriological quality of the lake's water should be checked by the agency responsible for the safety of the people utilizing the Refuge. Any portion of the lake which becomes contaminated by bacteria should be posted to water contact recreation. A density of 200 fecal coliforms per 100 ml has been adopted as an acceptable criteria for water contact recreation. 16/

SURVEY DESCRIPTION

Previous reports and studies indicate that a logical source of major pollution entering Buffalo Lake is uncontrolled runoff from cattle feedlots. 14,20,25,27,35/ In addition to the 11 feedlots in the Buffalo Lake watershed, there are municipal sewage treatment plants at Hereford and Friona. Also at Hereford are a large beet sugar refinery, numerous vegetable processing plants, and a small slaughter house. 25/ Wilson & Company has announced plans to build a multimillion-dollar packing plant at Hereford.

There are some individuals who feel that pesticides could be responsible for the fish kills at Buffalo Lake, although there was no evidence available to support such a conclusion. It has also been suggested that the large waterfowl population in residence at the lake during the winter months could be responsible for the bacterial contamination. 34/ Supposedly, the fecal material deposited by the waterfowl on the lake bottom during the winter would contribute large numbers of bacteria to the lake's water during the recreation season. Again, this hypothesis was not supported by the data available prior to this study. It should be noted that the sugar refinery retains its waste effluent in ponds, and then uses this water for irrigation.

The recorded fish kills at Buffalo Lake have occurred during periods of heavy rainfall and subsequent runoff. Available water quality data and other information suggest that only minor amounts of water pollutants reach Buffalo Lake during dry periods. 23/ Limited data indicate that Buffalo Lake is of satisfactory bacteriological quality for recreational use most of the time. 27/ Water quality data

collected during periods of runoff have shown very polluted conditions along Tierra Blanca Creek, Frio Draw, and in Buffalo Lake. [2,4]

On the east side of Hereford, Texas, and some 20 miles upstream from Buffalo Lake, are several cattle feedlots with a combined capacity in excess of 55,000 head. [25] On a daily basis, organic wastes from this number of cattle are well in excess of a city of 500,000 people. Normally there is no discharge from these feedlots; and since the mean annual rainfall is only 19 inches, runoff is very infrequent. As a result, the cattle droppings accumulate on the ground and are washed into the nearby stream when sufficient rainfall occurs. This rainfall and resultant runoff most often takes place in May and June during heavy thunderstorm activity. [3] In consideration of these factors, a four-phase plan was necessary to answer the questions posed in the Project Objectives.

The objective of Phase I was to acquire some background bacteriological data for all sample stations. In Phase II the two primary objectives were to acquire additional background bacteriological data, and to note the effect of recreational use on the bacteriological quality of Buffalo Lake. Phase III was dependent upon adequate rainfall, so that the effect of runoff on the receiving stream and Buffalo Lake could be noted. Data analyses and preparation of this report was carried out in Phase IV.

Sampling

In order to assess the water quality variations in Tierra Blanca Creek, Frio Draw, and Buffalo Lake, the Texas Water Quality Board

established the following sampling stations as shown in Figures 1 and 2 and described in Appendix A: 24/

a) six monthly sampling points along Tierra Blanca Creek;

b) one monthly sampling point on Frio Draw just above its confluence with Tierra Blanca Creek; and,

c) six monthly sampling points in Buffalo Lake.

The Texas Water Quality Board obtained samples for chemical, physical, and bacteriological analyses once a month for one year from each of the above stations. The chemical and physical samples were packed in ice and air-freighted to the Texas State Department of Health laboratory in Austin, Texas, for analyses. The monthly bacteriological samples taken by the Texas Water Quality Board were analyzed by the Amarillo Bi-City County Health Department for total coliform MPN only. Due to a lack of equipment, the Amarillo laboratory could not run membrane filter or fecal bacteria determinations. The monthly bacteriological samples collected in April 1968 were analyzed in the mobile laboratory and the samples collected in May 1968 were flown by chartered airplane to the FWPCA's Robert S. Kerr Water Research Center in Ada, Oklahoma, for analyses. The monthly bacteriological samples for June 1968 were inadvertently frozen during shipment and were not analyzed.

To determine the effect of various runoff induced waste discharges on the receiving stream's water quality, the Texas Water Quality Board established the following sample stations. These sampling stations are also shown in Figures 1 and 2 and described in Appendix A:

a) eight grab sample stations and two composite sample stations along Tierra Blanca Creek; and,

b) four grab sample stations and one composite sample station along Frio Draw.

Samples for chemical, physical, and bacteriological analyses were collected from each of these stations only during the periods of heavy runoff. The three composite stations correspond with three of the monthly sample stations. One additional point along Tierra Blanca Creek and two additional points along Frio Draw were sampled during part of the study. Three additional grab sample stations (shown in Figure 1) were established on Buffalo Lake during the project in order to better define the lake's bacteriological quality. Station 12 is classified as a lake station; however, during this study, the lake level was so low that the samples from station 12 more nearly represented the stream water as it slowly diffused into Buffalo Lake.

Bacteriological samples collected from both the monthly and grab stations during the runoff periods were analyzed in the mobile laboratory by research microbiologists from the Kerr Center. All bacteriological analyses performed by FWPCA personnel were by the membrane filter technique for total coliform, fecal coliform, and fecal streptococci. All three bacteriological parameters were used in order to better differentiate the various sources of pollution. A complete discussion of the bacteriological methods used in this survey will be found in Appendix B.

In summary, during a runoff period, 21 different locations along

the two streams and nine different locations in Buffalo Lake were sampled. Background water quality data were obtained on a monthly basis from seven stream sampling stations and six lake sampling stations.

Phase I

To determine the dry weather densities of the three bacterial parameters in Buffalo Lake and along Tierra Blanca Creek and Frio Draw and to begin work on the densities of these bacteria in the lake's bottom mud, the Phase I activities were initiated. On April 22, 1968, the mobile lab departed for Buffalo Lake, and the next day was hooked up to utilities at a site made available by the U. S. Fish and Wildlife Service. A few samples were analyzed to be sure all systems in the mobile lab were functioning properly. The necessary developmental work to perfect the mud bacteriological analyses was also completed during the check-out period. Basic water quality determinations were made for background information, and these data are shown in Appendix Table 1.

All 21 sampling points along Tierra Blanca Creek and Frio Draw were sampled on April 30 and May 1 for total coliform, fecal coliform, and fecal streptococci bacteria. Both surface water and bottom mud samples for bacteriological analyses were obtained from the six locations on Buffalo Lake. In addition, field determinations for dissolved oxygen, pH, temperature, and conductivity were made at all sampling points. Sampling was coordinated with personnel from the Texas Water Quality Board, and they collected the stream samples. The bacteriological results for Phase I are shown in Appendix Table 2. Water quality data taken during the sampling on April 30 are shown in Appendix Table 3.

The Texas staff obtained both water and bottom mud samples for pesticide analyses from representative stations along Tierra Blanca Creek, Frio Draw, and Buffalo Lake. The analyses of these samples were done by the FWPCA's Southeast Water Laboratory. The results of the pesticide analyses are shown in Appendix Table 4.

On June 4, 1968, a visit was made to Buffalo Lake for the purpose of showing representatives of the U. S. Public Health Service the mobile laboratory and conducting them on an aerial reconnaissance of the study area. It was apparent from the air that runoff from a 1.5 inch rain at Hereford on June 1 was entering Buffalo Lake from Tierra Blanca Creek. Arrangements were quickly made to sample the lake and these samples were returned to Ada and analyzed the same day. The results of the May 28 and June 4 samples are shown in Appendix Table 5. Water quality data collected during the June 4 sampling are shown in Appendix Table 6.

Phase II

The activities for Phase II were planned to answer the questions regarding:

a) the effect of extensive recreational use on the bacteriological quality of Buffalo Lake;

b) the densities of coliform, fecal coliform, and fecal streptococci bacteria along Tierra Blanca Creek, Frio Draw, and Buffalo Lake before a period of rainfall; and,

c) the densities of the three indicator groups of bacteria in the bottom mud of Buffalo Lake.

Samples from six of the seven monthly stream stations and all six lake stations were obtained on June 12 and 13 and analyzed in the mobile lab at Buffalo Lake. Surface sampling at all six lake stations and the Tierra Blanca Creek station south of Dawn, Texas, continued through June 17.

On June 14 and 15 bottom mud samples were obtained at all lake stations except number 12. Additional bottom mud samples were collected on June 16 and 17 from lake stations 8, 9, and 11. All samples were analyzed for all three bacterial parameters in order to evaluate the effect of recreational use over a weekend on the bacteriological quality of the lake. In addition, on June 12 sampling at four-hour intervals for 24 hours was initiated at station 8 and at the Tierra Blanca Creek station south of Dawn, Texas (station 6). These samples were analyzed for all three bacterial parameters to see if there was a pattern of variation in the bacteria densities with time of day. The daily sampling of the lake and its bottom mud over a weekend period was to indicate the effect, if any, of mixing and stirring due to motor boats. The bacteriological results for Phase II are shown in Appendix Table 7. Water quality data taken during the 24-hour sampling period are shown in Appendix Table 8.

Phase III

Phase III was considered the most important part of the project, but its initiation was dependent upon sufficient rainfall in the study area to produce adequate runoff. The work accomplished in Phase III was planned to answer the questions regarding:

a) the effect various waste sources have on the bacteriological quality of the receiving stream and Buffalo Lake;

b) the densities of coliform, fecal coliform, and fecal streptococci in Buffalo Lake and along Tierra Blanca Creek and Frio Draw after a rainfall period;

c) the fate of coliform, fecal coliform, and fecal streptococci bacteria entering Buffalo Lake; and,

d) the concentration of specific pesticides in Buffalo Lake and the concentration of these pesticides entering the lake from surface runoff.

The planned activities could have taken place at any time during the months of May, June, or July depending upon the occurrence of adequate rain.

During May and June the Texas Water Quality Board had personnel in the Hereford area surveying the various pollution sources along Tierra Blanca Creek and Frio Draw. Several small showers occurred during this period, but none produced sufficient runoff to justify initiation of Phase III. In the original plan for the project, it was thought that the required rainfall would occur during May or June; but since this did not happen, it was decided to remain alert for the proper conditions during July.

On Sunday evening, July 7, 1968, sufficient rainfall occurred for local observers to alert the Texas Water Quality Board's district supervisor in Lubbock, Texas. On Monday, July 8, the Board's district supervisor notified the FWPCA's project engineer that some runoff was occurring but that approximately 12 hours had elapsed since the rain

stopped; and as a consequence, the drainage ditches from the feedlots had already stopped flowing. It was decided to go ahead and initiate Phase III since the weather report predicted scattered thunderstorms continuing through the next afternoon. In addition, the probability of additional rainfall occurring later in July was becoming remote. To expedite sampling and analyses, project personnel were flown to Buffalo Lake by chartered airplane. The mobile lab was prepared and by 11:30 p.m. on the 8th, samples collected during that afternoon by the Texas Water Quality Board's district supervisor were being analyzed.

Sampling at all flowing stream stations and at all lake stations was conducted for the next two days (July 9 and 10). Sampling at the stream stations was discontinued on July 11 and preparations were made to discontinue all sampling after July 12.

On the evening of July 11 and continuing into the early morning of July 12, a thunderstorm localized over the main concentration of feedlots on the east side of Hereford resulted in runoff from the feedlots. Samples from all flowing stream stations were collected throughout the early morning hours of the 12th. Additional samples from the same stations were collected later the same day and also from the lake. Another rain similar to the one the previous evening occurred on the evening of July 12, but no special effort was made to sample the runoff induced by this rain. Samples were collected on July 13 from all flowing stream stations and from Buffalo Lake.

Samples of the initial runoff during the early morning hours of the 12th were collected and sent to the Texas State Department of

Health laboratory in Austin, Texas, for physical and chemical analyses. At the time of sampling, field measurements of temperature, pH, conductivity, and dissolved oxygen were made. Pesticide samples were collected on July 12 from stations 6, 11 and W, and the results obtained in the analyses are shown in Appendix Table 9.

Sampling of the lake and selected stream stations was continued through Monday, July 15, at which time it appeared that no further bacteriological effects of the runoff would be discernible. The bacteriological results for Phase III are shown in Appendix Table 10. The mobile lab was prepared for moving and upon the counting of the final plates on July 17, the mobile lab was moved to Ada. This completed the field activities of the project.

DATA INTERPRETATION

Phase I & II Stream Samples

The densities of coliform, fecal coliform, and fecal streptococci bacteria in Tierra Blanca Creek, Frio Draw, and Buffalo Lake during a normal dry period were determined in Phases I and II. The difficulty of estimating bacterial populations with only two sets of samples were immediately apparent as evidenced by the large range exhibited by the counts obtained at several sample stations. The counts at station 3 located just below the effluent from Hereford's sewage treatment plant, dramatically illustrated the adverse effect of Hereford's sewage on the bacteriological quality of Tierra Blanca Creek. The FC/FS (fecal coliform versus fecal streptococci) ratio of 7.0 calculated for station 3 was indicative of domestic sewage.

A rather inhospitable environment was afforded the indicator bacteria by Tierra Blanca Creek as shown by the rapid die-off of the bacteria in the short distance (0.71 miles) between stations 3 and 4. The FC/FS ratio also changes from station 3 to 4 with a ratio of 0.7 or less prevailing at station 4. This change in the ratio is due to the much more rapid die-off of fecal coliform than of fecal streptococci. In this study, the die-off of fecal coliform was in excess of ten times more rapid than the die-off of fecal streptococci. This difference in die-off may be partially explained by the fact that certain species of fecal streptococci, namely S. faecalis and S. faecalis var. liquifaciens, appear to be more resistant than most of the species in the fecal coliform group. [9/] Figure 3, a plot of the data obtained in Phase I,

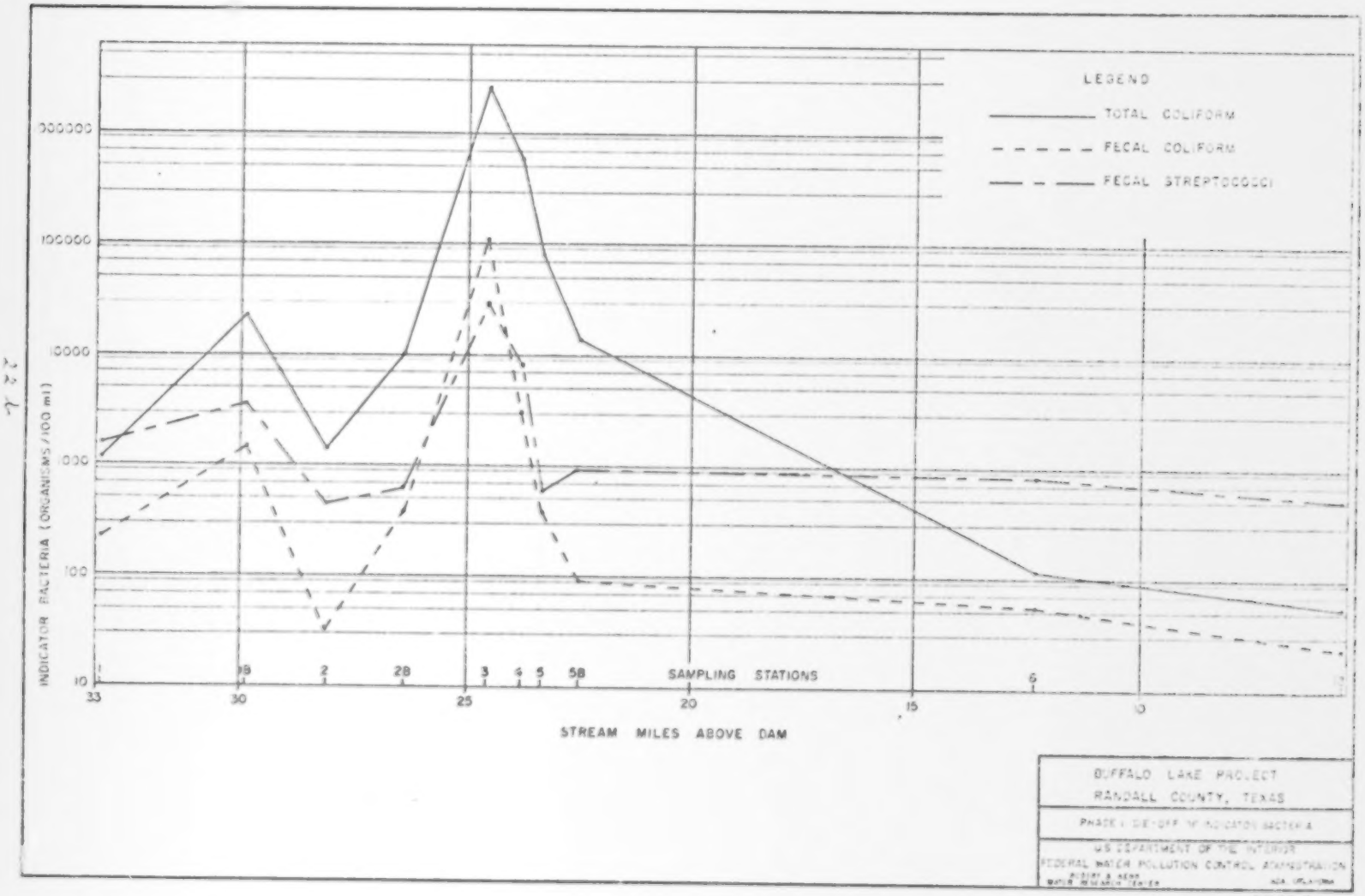
LEGEND
TOTAL COLIFORM
FECAL COLIFORM
FECAL STREPTOCOCCI
INDICATOR BACTERIA (ORGANISMS/100 ml)
1000000
100000
10000
1000
100
10
1
1B
2
2B
3
4
5
5B
6
SAMPLING STATIONS
33
30
25
20
15
0
STREAM MILES ABOVE DAM
BUFFALO LAKE PROJECT
RANDALL COUNTY, TEXAS
US DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION

FIGURE 3

clearly shows the die-off of the indicator bacteria below station 3.

A FC/FS ratio of 0.7 or less is considered to be indicative of fecal pollution from warm-blooded animals (other than man) and a FC/FS ratio of 4.0 or more is indicative of fecal pollution from man.[8,9,12,13] These ratios result from the preponderence of fecal coliforms found in man's feces and the greater numbers of fecal streptococci found in animal feces. S. bovis and S. equinus are the two predominate streptococci species found in cattle feces.[9,13] A FC/FS ratio of 0.7 or less was almost always found at all stream sampling stations except station 3. The high counts of fecal bacteria found in Tierra Blanca Creek and Frio Draw are indicative of recent fecal pollution. Under normal circumstances, the low value of the FC/FS ratio would indicate that a major portion of the fecal material was from warm-blooded animals (other than man). However, in this case the rapid die-off of the fecal coliform bacteria apparently is the cause of the low FC/FS ratio; and the fecal bacteria are from both human and animal sources.

A Chi Square Test for independent samples was performed to see if there was any statistically significant difference by stream sample station for each bacterial parameter between Phase I and Phase II. This test revealed a highly significant statistical difference between Phases I and II in the counts obtained for each parameter. A partitioning of the Chi Square for each parameter indicated that the difference was not the same for every station as shown in the tabulation that follows.[22]

Station	Change in Bacteria Counts From Phase I to Phase II		
	Total Coliform	Fecal Coliform	Fecal Streptococci
1	0	0	-
2	0	+	+
3	-	-	-
4	-	-	-
5	-	+	+
6	+	+	+

+ = increase 0 = no change - = decrease

A brief review of the data will quickly bear out the above stated conclusions that in Phase II there was a decrease in the counts obtained for all three bacterical parameters at stations 3 and 4, and an increase for all parameters at station 6. The lower counts obtained at stations 3 and 4 during Phase II, may have been due to a makeshift chlorinator temporarily installed in June by the City of Hereford at the sewage treatment plant. This chlorinator was not reliable and did not work on a continuous basis; therefore, no conclusions as to its effectiveness can be drawn. According to the data collected in Phase III, this chlorinator was no longer working a month after it was started.

Phase I & II Lake Samples

The waters of Buffalo Lake during Phase I were of excellent bacteriological quality. The cool water temperatures existing during Phase I, the lack of extensive refuge utilization, and the absence of runoff no doubt contributed to the low bacterial counts.

From previous observations, it was known that Buffalo Lake received its most concentrated recreational use on weekends; therefore,

Phase II was arranged to monitor the bacteriological quality of the lake prior to, during, and after a weekend period. In this manner any effect the recreational use had on the bacteriological quality of the lake could be determined. During Phase II an estimated 15,576 people visited Buffalo Lake, and 11,865 of these people came during the weekend. Approximately 60 percent of these people engaged in some sort of water contact recreation while at the lake.

A Chi Square Test was used to see if there was any significant difference in the total coliform counts obtained each day during Phase II. No significant difference in the daily total coliform counts was detected. The tabulation of mean ranks for each day shown below clearly illustrates the homogeneity of the daily total coliform counts.

Daily Mean Ranks

Parameter	Wed. 6/12	Thurs. 6/13	Fri. 6/14	Sat. 6/15	Sun. 6/16	Mon. 6/17
Total Coliform	25.3	32.35	25.25	22.82	21.90	30.64

The mean ranks were obtained by ranking the total set of data, then dividing the sums of the ranks for each day by the total number of observations made that day. Under the assumption that recreational use gives rise to increased total coliform counts, the mean ranks for Saturday, Sunday, and Monday should be greater than those for the remaining days. This assumption does not hold for the above data; therefore, it is concluded that water contact recreation during the weekend did not cause a notable increase in total coliform counts.

A Chi Square Test of homogeniety between the Phase I and

Phase II independent data sets showed that in Phase II there was a statistically significant increase in the concentration of all three bacterial parameters at each lake sampling station. Although several factors could have caused this increase, the data are not extensive enough to draw any conclusions as to why the bacterial concentrations were higher in Phase II. Higher water temperatures and increased utilization of the refuge may have contributed to the higher Phase II bacterial concentrations.

A non-parametric Kruskal-Wallis one-way analysis of variance test was used to see if the counts obtained at each lake sampling station in Phase II were significantly different. 22/ It was concluded from this test that the sampling stations were not homogenous. The tabulation below of mean ranks illustrates the disparity that exists in Phase II at each sampling station for the three parameters.

	Phase II Mean Ranks Sample Stations						
Parameter	7	8	8A	9	10	11	12
Total Coliform	37.4	30.1	22.4	12.7	15.7	10.8	47.9
Fecal Coliform	39.9	27.8	20.3	13.2	17.8	14.6	43.5
Fecal Strep	36.0	29.1	18.8	11.5	21.0	11.2	48.5

The larger the mean rank for a particular station, the higher the actual counts were as compared to another station. From this tabulation it is seen that the higher counts were at the stations (7,8,&8A) nearest the dam. These stations probably had higher concentrations of the indicator bacteria because of the recreational use patterns at the lake. Between stations 7 and 8 many people fished from the bank,

and floating refuse was often visible in this very narrow part of the lake.

Although water contact recreation did not increase the total coliform concentrations over a weekend period, recreational use does influence the concentration of indicator bacteria at individual stations. It should be noted that station 12 is located at the very upper end of Buffalo Lake where Tierra Blanca Creek enters the lake. The channel at station 12 was no more than 20 feet wide, and the water was so shallow as to preclude any recreational use other than fishing. Even with the increase in the three bacteria indicators found in Phase II, the waters of Buffalo Lake were still of satisfactory bacteriological quality for water contact recreation.

The results of the 24-hour sampling at stations 6 and 8 were analyzed using a rejection of outliers test procedure developed by Dixon and Massey. 6/ No individual bacteria count was rejected by the test; therefore, the data show no evidence of diurnal variation in the three bacterial parameters.

The monthly samples collected on May 28, 1968, tended to confirm the results obtained during Phase I. The special samples collected on June 4 indicated that at the time of sampling the bacteriological quality of Buffalo Lake had not been adversely affected by any runoff. The counts at station 12 on June 4 were higher than previously had been recorded, but these counts were well within values normally found in a stream. The recording flow gage located between stations 6 and 12, indicated that the runoff entering Buffalo Lake due to the rain on June 1 only amounted to approximately 30 acre-feet.

The mud samples collected during Phase I and Phase II for bacteriological examination did not reveal any significant densities of the three bacterial groups. In a few isolated cases, definite concentrations of the indicator bacteria were found. These cases are so few and scattered that they must be considered unusual circumstances of doubtful significance. The results of the mud bacteriological analyses are reported as less than values at the minimum detectable level. The mud clogged the pores of the membrane filter and made it impossible to filter a sufficient quantity of sample to capture any bacteria on the membrane. The concentration of the three bacterial indicators present in the bottom mud of Buffalo Lake do not appear to be sufficient to cause any bacteriological quality problems in the overlying waters of the lake.

The pesticide results for both mud and water as reported in Appendix Table 4 are all less than the minimum detectable limits. Pesticide concentrations, many fold in excess of the values reported, would be required for any toxicity problems to become apparent. It is concluded that at the time of sampling, no pesticide concentrations of any significance existed in the mud or waters of Frio Draw, Tierra Blanca Creek, or Buffalo Lake.

Phase III

Phase III was initiated on July 8, 1968, under less than ideal conditions, because of the weekend induced time lag between rainfall and sampling. It had been realized from the beginning that immediate sampling of runoff waters would be necessary because of the short

intense nature of the thunderstorm induced rains and the short duration of the resulting runoff. The decision to go ahead was made, fully realizing that the major portion of the runoff had entered the creek and that no differentiation of pollution sources would be possible.

The rain on July 7, 1968, produced the most substantial runoff of the year in Tierra Blanca Creek. The flow record obtained at the U. S. Geological Survey gage located 3.29 miles below station 6 recorded a peak discharge of 418 cfs at 6 a.m. on July 8. However, the runoff was short-lived and only 447 acre-feet of water entered Buffalo Lake. Figure 4 shows the discharge record obtained at this gage together with available rainfall records. The rainfall record shown in Figure 4 is from the U. S. Weather Bureau; however, because of the scattered nature of the rain, the official rain gages can often give a misleading picture. The usual rainfall in the study area during the summer results from thunderstorm activity,and very heavy rains may occur in one area, while another area close by may receive only a sprinkle. Another factor complicating correlation of rainfall, runoff, and stream discharge is the very heavy withdrawal of water from the stream for irrigation purposes. Many times sampling stations were dry because the available stream flow was being accumulated above the station and pumped from the stream for irrigation. Many irrigation pumps continued to run even during periods of precipitation.

The peak runoff had passed on July 8 before any samples were collected; however, the results clearly show that large numbers of the three bacterial indicators had entered Tierra Blanca Creek since

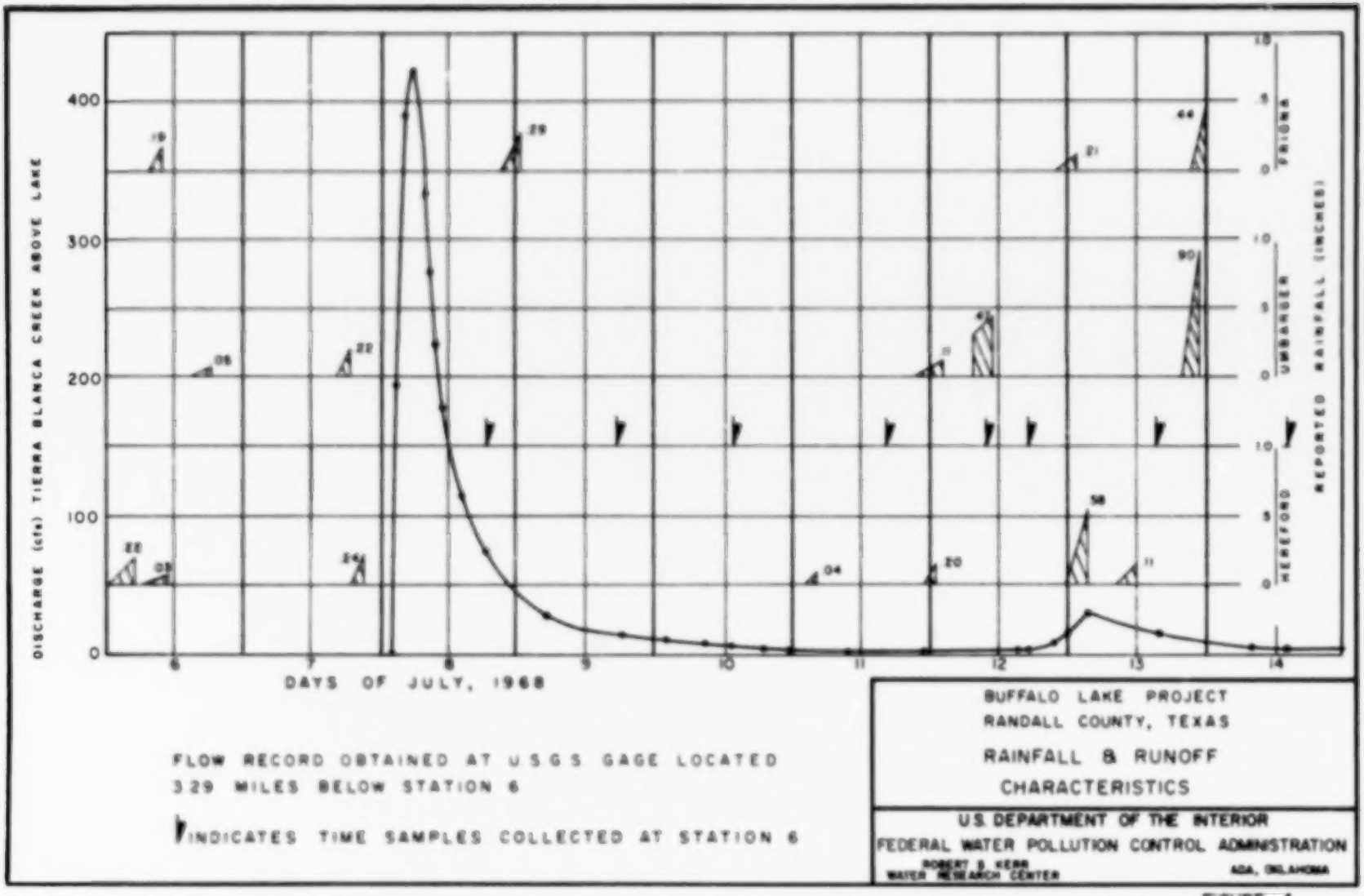
DISCHARGE (cfs) TIERRA BLANCA CREEK ABOVE LAKE
400
300
200
100
0
6
7
8
9
10
11
12
13
14
DAYS OF JULY, 1968
REPORTED RAINFALL (INCHES)
FRIONA
UMBARGER
HEREFORD
FLOW RECORD OBTAINED AT U S G S GAGE LOCATED 3.29 MILES BELOW STATION 6
INDICATES TIME SAMPLES COLLECTED AT STATION 6
BUFFALO LAKE PROJECT
RANDALL COUNTY, TEXAS
RAINFALL & RUNOFF CHARACTERISTICS
U.S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
ROBERT S. KERR WATER RESEARCH CENTER
ADA, OKLAHOMA

FIGURE 4

the previous sampling in Phase II. Some idea of the very large bacterial counts that must have been present in the leading edge of the runoff can be gained by observing the station 6 results for July 8. This sample was collected approximately 13 hours after the peak flow had passed station 6, yet the bacterial counts were extremely high and indicated the presence of gross pollution. The fecal streptococci count at station 6 on July 8 was 870,000/100ml, whereas the highest previous value was 3,400/100ml. Extremely high bacterial counts were also obtained at the creek's entrance into Buffalo Lake at station 12.

Samples collected from Buffalo Lake on July 9, 1968, indicated that the upper end of Buffalo Lake at stations 10 and 11 was grossly contaminated with bacteria of fecal origin. The fecal coliform count was 26,000/100ml at station 10 and 29,000/100ml at station 11. At the time of sampling on July 9, people were observed swimming from the banks opposite both stations 10 and 11. This area is a popular place for people with small children to swim, because of the lake's gently sloping bottom, and a maximum depth of only 1.5 to 2.0 feet. Because of the shallow depth, boats of any size cannot reach stations 10 and 11 without great difficulty.

The bacteria found in the upper end of Buffalo Lake on July 9 did not spread throughout the reservoir. Apparently, die-off due to environmental factors, including settling and dilution, prevented the high bacterial densities from affecting the major portion of the lake. On July 10 the counts at stations 10 and 11 were considerable reduced; however, a sample collected at station 9A, approximately one mile

down-reservoir from station 10, showed a significant increase over the other lake stations nearer the dam.

In 1967 when all of Buffalo Lake became contaminated with bacteria, a total of 2,875 acre-feet of runoff entered the lake between June 7 and June 30. This is in contrast to the 445 acre-feet of runoff entering the lake in 1968 between July 8 and July 20. It is most probable that if the 1968 runoff had been larger, the entire lake would have again been contaminated. However, the dilution and self-purification powers of Buffalo Lake were able to quickly reduce the densities of bacteria which gained entrance into the lake during July 1968.

Just before midnight on July 11 and continuing into the early morning hours of July 12, at least one inch of rain fell over the main concentration of feedlots just east of Hereford. Sampling of Tierra Blanca Creek was begun by 1 a.m., but a short delay was soon encountered while additional sample bottles were secured.

All samples collected during the early morning of July 12 from Tierra Blanca Creek above station 6 showed increased counts above those previously obtained. The exceptional high streptococci counts obtained in the first samples collected on July 12 at stations 4 and 5 are indicative of recent fecal pollution from cattle. Figure 5 clearly illustrates the dramatic effect the runoff had on the densities of fecal bacteria in Tierra Blanca Creek. The second samples taken on July 12 at stations 4 and 5 show much lower fecal streptococci counts, because the direct runoff from the feedlots had already stopped.

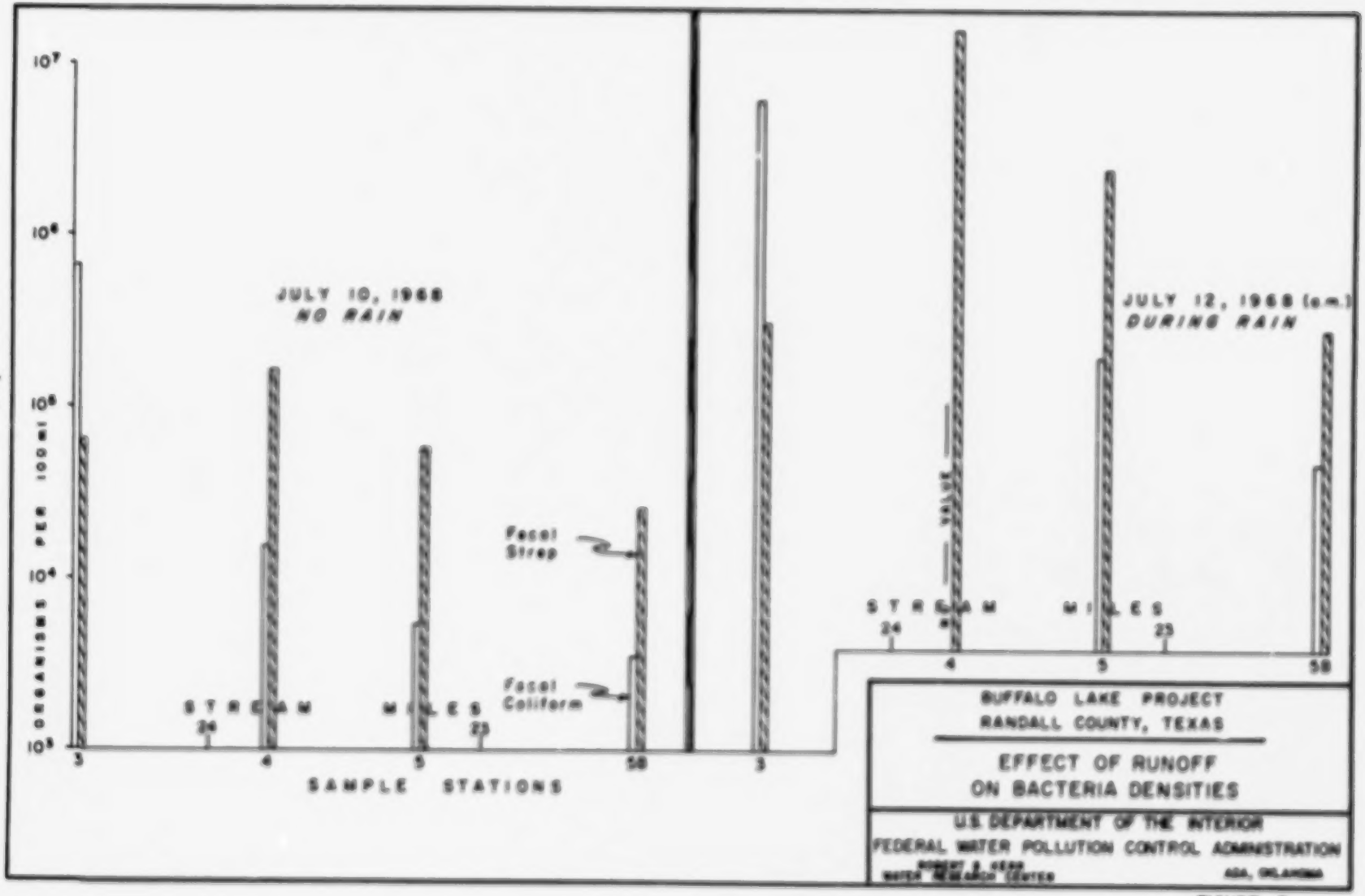
ORGANISMS PER 100 ml
10^7
10^6
10^5
10^4
10^3
JULY 10, 1968
NO RAIN
JULY 12, 1968 (a.m.)
DURING RAIN
Fecal Strep
Fecal Coliform
STREAM MILES
24
23
5B
3
4
5
SAMPLE STATIONS
BUFFALO LAKE PROJECT
RANDALL COUNTY, TEXAS
EFFECT OF RUNOFF
ON BACTERIA DENSITIES
U.S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
ROBERT S. KERR
WATER RESEARCH CENTER
ADA, OKLAHOMA

FIGURE 5

The relatively lower fecal streptococci counts obtained at stations 5B and 5C compared to those at 5 were, no doubt, due to a dike holding back the runoff. Because of the water behind the dike, station 5C was almost impossible to get to, and the data are not as complete as would be liked; however, there is no question but that a dike is an effective, though somewhat imperfect, means of preventing highly polluted surface runoff from entering Tierra Blanca Creek. The water contained behind the dike was grossly contaminated with bacteria as evidenced by the results of the samples taken at station 5D. The 76,000,000 fecal streptococci per 100 ml found at station 5D was the highest fecal streptococci count encountered during the project.

A comparison of the results obtained at stations A and B shows that large quantities of the indicator bacteria entered the runoff as it flowed through the feedlots. This runoff, however, was prevented from reaching Tierra Blanca Creek by a dike built across the tributary as shown in Figure 2. In a like manner, the results for stations C and D show that large quantities of bacteria were added to the airport tributary as it received runoff from a feedlot. This runoff did enter Tierra Blanca Creek below station 5C (see Figure 2).

The feedlot located on both sides of Frio Draw between stations Y1 and W contributed substantial quantities of the indicator bacteria to Frio Draw. No water was discharged from Frye Lake during the study and the samples collected at station W reflect irrigation tail water and runoff from pasture land.

The tabulation below of mean ranks indicates which sampling stations had bacteria counts higher or lower than the adjoining upstream and downstream stations.

Parameter	Phase III Mean Ranks Sample Stations									
	1	1B	2	2B	3	4	5	5B	5D	6
Total Coliform	8	21	18	32	62	53	46	39	58	28
Fecal Coliform	8	29	12	28	61	52	46	21	63	33
Fecal Strep	9	23	15	28	50	52	53	49	65	34

As can be seen from the table, there is an increase in all three of the bacterial parameters from stations 1 to 1B and from stations 2 to 2B. The increase between 1 and 1B is probably due to a feedlot located just above station 1B. This feedlot has a dike to prevent its runoff from entering Tierra Blanca Creek; otherwise, the difference in bacteria counts between stations 1 and 1B would probably have been much greater. The increase in the indicator bacteria counts shown between stations 2 and 2B may be due to urban runoff from the City of Hereford.

The above tabulation shows that the fecal streptococci increased downstream from station 3. These increases indicate that fecal pollution from animal sources other than man is entering Tierra Blanca Creek between stations 3 and 5B.

The rains of July 11, 12, and 13 created only 60 acre-feet of inflow into Buffalo Lake; and the effect of this inflow on the bacteriological quality of the lake was barely discernible. The tabulation of mean ranks shown below indicates which sampling stations in

Buffalo Lake had the highest counts of the three bacterial parameters.

Phase III Mean Ranks

Parameter	Sample Stations								
	7	8	8A	8B	9	9A	10	11	12
Total Coliform	21	18	13	12	10	26	40	36	48
Fecal Coliform	20	13	10	7	16	33	41	38	49
Fecal Strep	21	14	8	4	24	33	41	42	52

A reversal in the high count stations took place in Phase III in that stations 7, 8, and 8A had the lowest counts, instead of the highest counts as in Phase II. This reversal is due to the bacteria being brought into Buffalo Lake by the runoff water. The major source of the fecal bacteria in Buffalo Lake is surface runoff. Uncontrolled surface drainage from large cattle feedlots contributes large quantities of all three bacterial parameters to the waters of Tierra Blanca Creek and Frio Draw.

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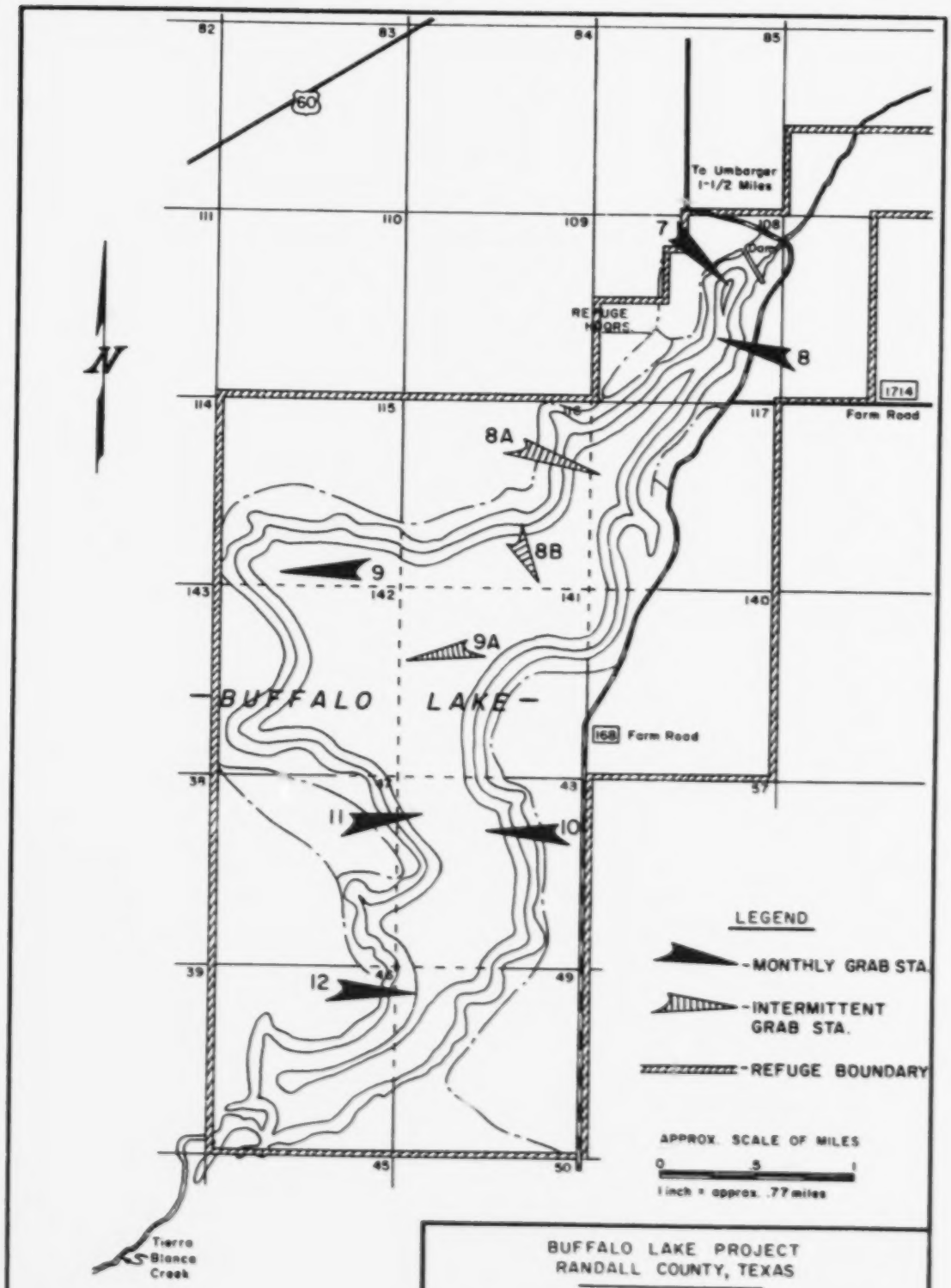
82
83
84
85
60
To Umbarger
1-1/2 Miles
111
110
109
108
7
Dam
REFUGE
HQRS.
8
1714
Farm Road
114
115
117
8A
8B
9
143
142
141
140
9A
BUFFALO LAKE
168
Farm Road
39
43
57
11
10
39
49
12
45
50
N
LEGEND
-MONTHLY GRAB STA.
-INTERMITTENT GRAB STA.
-REFUGE BOUNDARY
APPROX. SCALE OF MILES
0
5
1
1 inch = approx. .77 miles
Tierra Blanca Creek
BUFFALO LAKE PROJECT
RANDALL COUNTY, TEXAS
BUFFALO LAKE LOCATION MAP
U.S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
ROBERT S. KERR WATER RESEARCH CENTER
ADA, OKLAHOMA

FIGURE 1

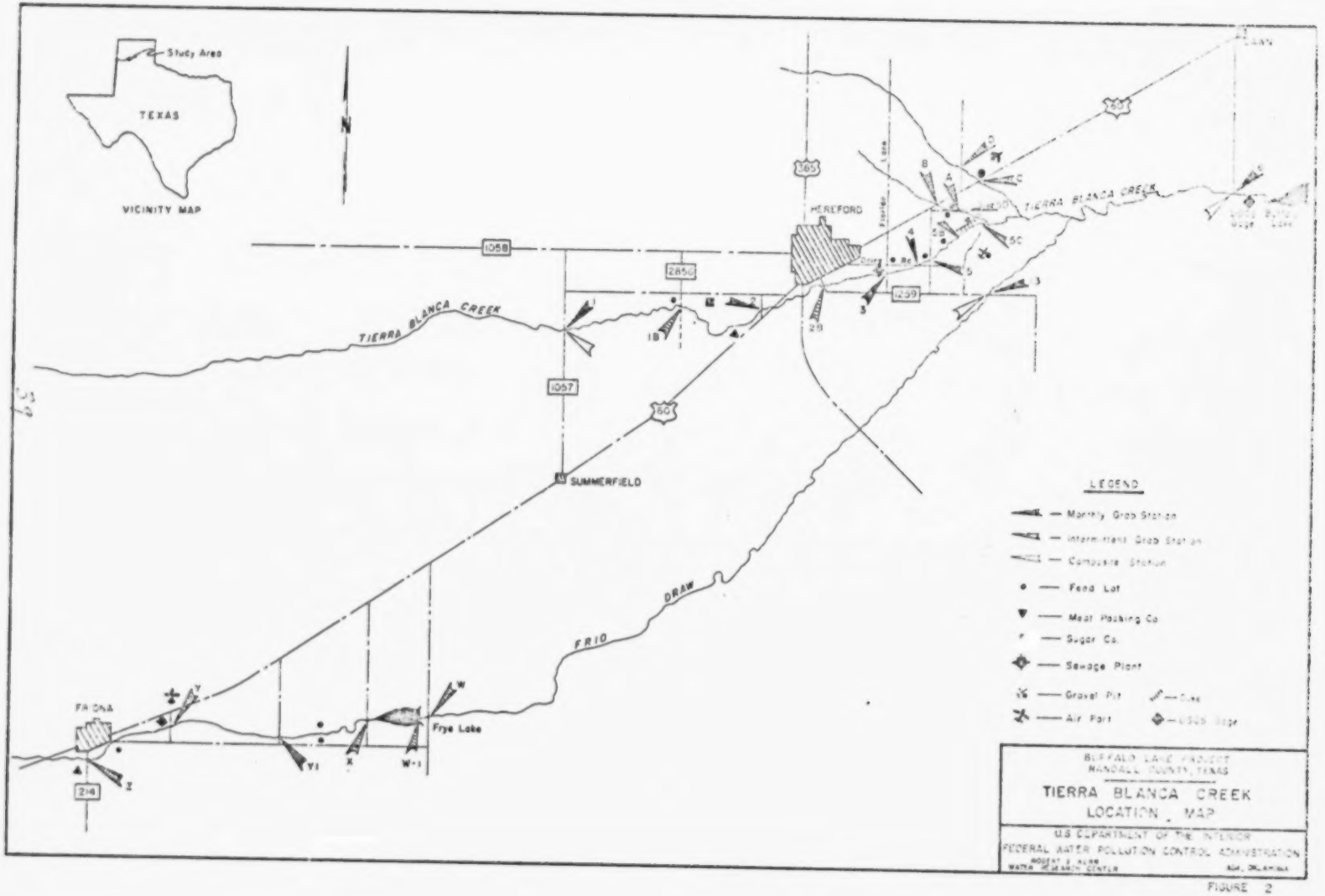
Study Area
TEXAS
VICINITY MAP
HEREFORD
TIERRA BLANCA CREEK
TIERRA BLANCA CREEK
SUMMERFIELD
FRIO DRAW
Frye Lake
FRIONA
1058
2650
1057
385
60
LEGEND
— Monthly Grab Station
— Intermittent Grab Station
— Composite Station
— Feed Lot
— Meat Packing Co.
— Sugar Co.
— Sewage Plant
— Gravel Pit
— Air Port
BUFFALO LAKE PROJECT
RANDALL COUNTY, TEXAS
TIERRA BLANCA CREEK
LOCATION MAP
U.S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION

FIGURE 2

APPENDIX A
DESCRIPTION OF SAMPLING STATIONS
BUFFALO LAKE PROJECT

Station Number	Description	Distance From Dam (miles)	Distance From Tierra Blanca Creek (miles)
7	Buffalo Lake near Dam NE/4 of Sec. 108	.14	
8	Buffalo Lake at First Buoy Line SE/4 of Sec. 108	.47	
8A	Buffalo Lake opposite East Bank Boat Ramp, NW/4 Sec. 117	1.47	
8B	Buffalo Lake opposite Ski Jump and new Boat Dock, SE/4 Sec. 116	2.10	
9	Buffalo Lake at Spring Bay, SW/4 Sec. 115	3.47	
9A	Buffalo Lake opposite Station 9 in Middle of Lake, NW/4 Sec. 141	2.90	
10	Buffalo Lake Upper End near East Side, NE/4 Sec. 48	3.90	
11	Buffalo Lake Upper End near West Side, NW/4 Sec. 48	3.76	
12	Buffalo Lake and Tierra Blanca Creek Confluence at End of Lake Access Road NW/4 Sec. 49	5.47	
6	Tierra Blanca Creek at County Road South of Dawn (Dawn Road)	12.29	
	Confluence of Frio Draw with Tierra Blanca Creek	18.87	
13	Frio Draw at FM Road 1259	22.56	3.69
W	Frio Draw below Frye Lake at N-S County Road Culvert	41.67	22.80
W1	Frye Lake at Dam	41.77	22.90

APPENDIX A (Continued)
DESCRIPTION OF SAMPLING STATIONS
BUFFALO LAKE PROJECT

Station Number	Description	Distance From Dam (miles)	Distance From Tierra Blanca Creek (miles)
X	Frio Draw below Friona Feed Yards at N-S County Road Culvert	43.08	24.21
Y1	Frio Draw above Friona Feed Yards at N-S County Road Culvert	45.77	26.90
Y	Frio Draw below Friona STP at N-S County Road Culvert South of Airfield	49.87	31.00
Z	Frio Draw at FM Road 214 at Friona	52.77	33.90
	Confluence of Airport Tributary with Tierra Blanca Creek	20.27	
C	Airport Tributary at Santa Fe Railroad Bridge	21.90	1.63
D	Airport Tributary at N-S County Road Culvert above Western Feed Yard	22.39	2.12
	Confluence of Hereford Feed Lot Tributary with Tierra Blanca Creek	21.27	
5D	Runoff Water Retained behind Hereford Feed Yards Dike	22.02	.75
A	Hereford Feed Yard's Tributary above Retaining Pond	22.27	1.00
B	Hereford Feed Yard's Tributary at US Highway 60	22.77	1.50
5C	Tierra Blanca Creek below Gravel Pit at Low Head Dam	21.37	
5B	Tierra Blanca Creek above Gravel Pit near Fence	22.42	
5	Tierra Blanca Creek at Third Bridge below STP (N-S County Road)	23.22	

APPENDIX A (Continued)
DESCRIPTION OF SAMPLING STATIONS
BUFFALO LAKE PROJECT

Station Number	Description	Distance From Dam (miles)	Distance From Tierra Blanca Creek (miles)
4	Tierra Blanca Creek at Second Bridge below STP (Dairy Road)	23.77	
3	Tierra Blanca Creek below Hereford STP at Florida Lane (Progressive Road)	24.48	
2B	Tierra Blanca Creek at FM Road 1259	26.37	
2	Tierra Blanca Creek at First Bridge upstream (Kingwood St.) from US Highway 60 Bridge	28.07	
1B	Tierra Blanca Creek below Holly Feedlot at N-S County Road	29.87	
1	Tierra Blanca Creek at FM Road 1057	33.07	
	Tierra Blanca Creek at New Mexico State Line	66.07	
	USGS stream flow gage on Tierra Blanca Creek above Buffalo Lake	9.0	

APPENDIX B
BACTERIOLOGICAL METHODS
BUFFALO LAKE PROJECT

A mobile laboratory properly equipped for bacteriological analyses was set up at the Buffalo Lake National Wildlife Refuge. All bacteriological samples were analyzed in the mobile laboratory except the monthly samples collected on May 28 and the special samples of June 4. The samples were iced after collection and every effort was made to allow no more than four hours to elapse between collection and analyses.

The procedures used in the determination of the coliform group and fecal streptococcal group were essentialiy those from the Twelfth Edition of Standard Methods for membrane filter.[33] The media used for the fecal streptococci determination was KF Streptococcus Agar as recommended by Kenner, et al. [1] The KF agar was used because of its apparent higher recoveries of S. bovis and S. equinus. The TTC used in the KF agar was obtained from Eastman Organic Chemicals.

For the enumeration of the fecal coliform group, m-FC Broth Base as recommended by Geldreich, et al, was used. [7] Whirl-Pak plastic bags were used to hold the fecal coliform plates while they were incubated completely submerged in a water bath for 24 hours at 44.5°C. Every effort was made to place the bags in the water bath within 30 minutes of the first membrane being placed in the bag. The tabulation below shows the essential details for each of the bacteriological methods used in this study.

Specifications for Bacteriological Tests

Test	Medium Used	Incubation Temperature	Time of Incubation
Total Coliform	M-Coliform Broth(B.B.L.)	35°C±.5°	22-24
Fecal Coliform	m-FC Broth Base(Difco)	44.5°C±.5°	24±2
Fecal Streptococci	KF Streptococcus Agar(Difco)	35°C±.5°	48-2

The membranes used in this study were sterile, standard Millipore filters, No. HA, white with grid, 47mm in diameter, and a pore size of 0.45μ. Sterile 60mm plastic petri dishes with sterile absorbent pads were used except pads were not needed for the fecal streptococci tests. Ultraviolet light was used to sterilize the filter holder assemblies after each filtering. A steam autoclave and hot air oven were used to sterilize all dilution water, media, and glassware. Sterile, phosphate-buffered dilution water was used to appropriately dilute the samples and to rinse the samples through the filter holder assembly. A stereoscopic variable power microscope with a fluorescent light suspended beneath the scope and shining perpendicularly on the membrane was used for counting.

Mud Samples

The method used for the bacteriological examination of lake bottom mud samples was patterned after that developed by Geldreich and Van Donsel.[10/] Samples were obtained with an Ekman sampler and the top inch of mud collected was spooned into sterile Whirl-Pak bags for transport to the mobile laboratory. Using aseptic techniques, each individual mud sample was emptied into a sterile 250 ml graduated cylinder. The mud was allowed to settle for 30-60 minutes or until settling was stablized. The volume of the settled mud was read off on the graduate, and enough sterile phosphate buffered water was added to give the mixture twice the volume of the settled mud. This mixture was considered a 1:2 dilution of the mud sample. The contents of the graduate were then emptied into a sterile, wide-mouth bottle, thoroughly shaken (with glass beads if necessary to break up clumps), and from this further necessary dilutions were made in standard milk dilution bottles.

Methods used in testing for the three different groups of bacterial indicators of pollution were identical to those for the examination of water. However, due to clogging of the pores of the filters by the mud particles, the volume of mud sample that could be filtered through was limited. Because of this limitation, when the bacterial densities are low as in these lake bottom mud samples, it was only possible to determine the upper threshold of the samples for each of the indicators. These limitations of the membrane filter procedure were fully understood prior to the study, but the limited space and other facilities available in the mobile laboratory made the Multiple Tube Fermentation Technique or Pour Plate Technique impractical.

APPENDIX C
LIST OF PARTICIPANTS
BUFFALO LAKE PROJECT

Listed below are those persons who played a significant part in the FWPCA portion of the Buffalo Lake Project. Without the help of these people and the agencies they represent, this study would have been severely limited, if not impossible.

Texas Water Quality Board

Joe Teller, Deputy Director

Joe Sorrels, Director Field Operations

Dick Whittington, Project Engineer

Bill Hunkler, District Supervisor

Dick Respers, Biologist

Ken Cave, Biologist

George Tillson, Hydrologist

Carl Hickum, Engineering Technician

Bob Bradshaw, Engineering Technician

Texas Parks and Wildlife Department

Jack E. Crabtree, District Biologist

Texas State Department of Health

Millard Bruce, Sanitarian

U. S. Fish & Wildlife Service, Bureau of Sport Fisheries & Wildlife

Gordon H. Hansen, Refuge Manager (to June 1, 1968)

Paul Ferguson, Refuge Manager (from June 1, 1968)

Dick Gritman, Assistant Refuge Manager

U. S. Public Health Service

Charles W. Northington, Water Hygiene Representative

Warren Norris, Sanitary Engineer

E. E. Geldreich, Research Microbiologist

City of Hereford, Texas

Dudley Bayne, City Manager

FWPCA Project Personnel

The following staff members of the Technical Services Program of the Robert S. Kerr Water Research Center were responsible for the planning and execution of the project, in cooperation with the above named agencies and individuals.

Richard Duty, Chief, Technical Services Program

Robert H. Reeves, Sanitary Engineer and Project Director

S. C. Yin, Project Microbiologist

James McNabb, Microbiologist

James E. Moyer, Research Microbiologist

Ralph D. Harkins, Mathematical Statistician

Robert E. Crowe, Supervisory Chemist

Grady Campbell, Electronics Technician

Lan Vandeveer, Draftsman

Tommy Redman, Draftsman

Nancy Marlow, Secretary

Bill Loy, Pesticide Chemist, Southeast Water Laboratory, Athens, Georgia

APPENDIX TABLE 1
INITIAL RECONNAISSANCE WATER QUALITY
BUFFALO LAKE PROJECT

Sample Station & Depth	Date & Time	Air Temp. (°F)	Water Temp. (°F)	pH (units)	Conductivity (μmhos/cm)	Dissolved Oxygen (mg/l)	Water Depth (ft.)
7 Surface	4/24/68 1750	65	56	9.1	1,520	10.8	13.0
8 Surface	4/24/68 1715	64	55	9.2	1,520	10.8	10.0
9 Surface	4/24/68 1645	64	55	9.0	1,520	11.5	5.0
10 Surface	4/24/68 1500	68	64	8.8	1,600	9.6	1.5
11 Surface	4/24/68 1600	67	59	9.0	1,520	12.0	1.5

Note: Weather on April 24, 1968, was calm and partly cloudy

1 Surface	4/25/68 1700	72	64	10.1	590	20.0	1.5
2 Surface	4/25/68 1615	75	68	9.8	600	16.0	2.5
3 Surface	4/25/68 1245	78	61	9.2	1,900	4.8	1.5
4 Surface	4/25/68 1220	68	59	9.6	1,850	20.0	2.0
5 Surface	4/25/68 1200	67	58	9.4	1,720	18.2	1.0
6 Surface	4/25/68 1100	64	60	9.4	1,380	10.8	2.0

Note: Weather on April 25, 1968, was clear and sunny with a North wind estimated at 5 mph.

DO determined by Azide Modification of Winkler Method using 0.1 ml graduated burette.

APPENDIX TABLE 2
PHASE I BACTERIOLOGICAL RESULTS
BUFFALO LAKE PROJECT

Sampling Station	Date of Collection	Time of Collection	Total Coliform /100 ml	Fecal Coliform /100 ml	Fecal Streptococci /100 ml	FC/FS* Ratio
1	4/30/68	0845	500	50	360	0.1
	5/01/68	AM	1,900	460	3,000	0.2
1-B	4/30/68	1720	20,000	1,600	5,700	0.3
	5/01/68	AM	25,000	1,600	1,800	0.9
2	4/30/68	0915	1,100	20	300	0.07
	5/01/68	AM	2,000	50	620	0.08
2-B	4/30/68	1730	5,000	400	480	0.8
	5/01/68	AM	16,000	390	810	0.5
3	4/30/68	0935	2,300,000	210,000	30,000	7.0
	5/01/68	AM	2,700,000	210,000	30,000	7.0
4	4/30/68	0950	90,000	1,000	6,000	0.2
	5/01/68	AM	890,000	4,700	8,800	0.5
5	4/30/68	Station was dry due to upstream pumping for irrigation.				
	5/01/68	AM	82,000	390	570	0.7
5-B	4/30/68	1745	< 10,000	< 1,000	< 1,000	
	5/01/68	AM	14,000	90	900	0.1
6	4/30/68	1030	160	80	600	0.1
	5/01/68	AM	70	30	950	0.03
7	4/30/68	1130	18	0	3	0.0
	5/01/68	1215	11	4	15	0.3
8	4/30/68	1115	8	2	7	0.3
	5/01/68	1205	12	2	21	0.1
9	4/30/68	1100	3	1	5	0.2
	5/01/68	1150	2	2	3	0.7
10	4/30/68	1005	3	4	15	0.3
	5/01/68	1140	0	0	3	0.0
11	4/30/68	1035	2	1	10	0.1
	5/01/68	1130	0	0	5	0.0

* FC = Fecal Coliform; FS = Fecal Streptococci

APPENDIX TABLE 2 (Continued)
PHASE I BACTERIOLOGICAL RESULTS
BUFFALO LAKE PROJECT

Sampling Station	Date of Collection	Time of Collection	Total Coliform /100ml	Fecal Coliform /100 ml	Fecal Streptococci /100 ml	FC/FS Ratio
12	4/30/68	1230	45	13	160	0.08
	5/01/68	PM	57	30	800	0.04
W	5/01/68	1015	2,700	150	4,200	0.04
	5/01/68	PM	560	140	38,000	0.004
X	5/01/68	1000	9,100	2,800	31,000	0.09
	5/01/68	PM	1,700	380	18,300	0.02
Y	5/01/68	0850	630	100	450	0.2
	5/01/68	PM	150	40	590	0.1
Y-1	5/01/68	0955	900	34	4,500	0.008
	5/01/68	PM	1,300	280	6,000	0.05
Z	5/01/68	0900	7,700	2,900	9,800	0.3
	5/01/68	PM	4,100	1,300	14,500	0.09
7-M △	4/30/68	1130	30,000	< 1,000	1,000	
	5/01/68	1215	< 1,000	< 1,000	< 1,000	
8-M	4/30/68	1115	< 1,000	< 1,000	< 1,000	
	5/01/68	1205	< 1,000	< 1,000	< 1,000	
9-M	4/30/68	1100	< 1,000	< 1,000	< 1,000	
	5/01/68	1150	< 1,000	< 1,000	6,000	
10-M	4/30/68	1005	< 1,000	< 1,000	< 1,000	
	5/01/68	1140	< 1,000	< 1,000	4,000	
11-M	4/30/68	1035	< 1,000	< 1,000	< 1,000	
	5/01/68	1130	< 1,000	< 1,000	1,000	

△ M = Bottom Mud Sample

APPENDIX TABLE 3
PHASE I WATER QUALITY
BUFFALO LAKE PROJECT

Sample Station & Depth	Date & Time	Air Temp. °F	Water Temp. °F	pH (units)	Conductivity (μmhos/cm)	Dissolved Oxygen (mg/l)
7 Surface	4/30/68 1315	72	64	10.2	1520	13.0
8 Surface	4/30/68 1415	72	62	10.0	1510	12.2
9 Surface	4/30/68 1445	74	59	10.0	1520	11.4
10 Surface	4/30/68 1005	60	58	9.2	1500	8.8
11 Surface	4/30/68 1035	62	56	9.4	1500	11.2

APPENDIX TABLE 4
RESULTS OF PESTICIDE ANALYSES
BUFFALO LAKE PROJECT

Water Grab Samples Taken 5-1-68

Sampling Station	SEWL #	Dieldrin ppb	Malathion ppb	Parathion ppb	DDT ppb	2,4-D ppb	Di-Syston ppb	Methyl Parathion ppb
Station #8	5863	<0.05	<0.10	<0.10	<0.10	<0.5	<0.10	<0.10
Station #11	5864	<0.05	<0.10	<0.10	<0.10	<0.5	<0.10	<0.10
Station #1	5865	<0.05	<0.10	<0.10	<0.10	<0.5	<0.10	<0.10
Station #6	5866	<0.05	<0.10	<0.10	<0.10	<0.5	<0.10	<0.10
Station X	5867	<0.05	<0.10	<0.10	<0.10	<0.5	<0.10	<0.10

Mud Samples Taken 5-31-68

Sampling Station	SEWL#	Dieldrin ppm	Malathion ppm	Parathion ppm	DDT ppm	Di-Syston ppm	Methyl Parathion ppm
Station #8	5894	<0.01	<0.01	<0.01	<0.1	<0.01	<0.01
Station #11	5895	<0.01	<0.01	<0.01	<0.1	<0.01	<0.01
Station #1	Sample broken in shipment						
Station #6	5893	<0.01	<0.01	<0.01	<0.1	<0.01	<0.01
Station X	5896	<0.01	<0.01	<0.01	<0.1	<0.01	<0.01

Note: Water sample results are given in parts per billion (ppb) and mud sample results are given in parts per million (ppm). Values given represent the limits of detection.

APPENDIX TABLE 5
MAY & SPECIAL SAMPLING BACTERIOLOGICAL RESULTS
BUFFALO LAKE PROJECT

Sample Station	Date of Collection	Total Coliform /100 ml	Fecal Coliform /100 ml	Fecal Streptococci /100 ml	FC/FS* Ratio
1	5/28/68	2,300	290	1,700	0.2
2	5/28/68	500	290	270	1.1
3	5/28/68	19,000,000	5,900,000	190,000	31.0
4	5/28/68	190,000	42,000	3,100	14.0
5	5/28/68	17,000	2,100	12,200	0.2
6	5/28/68	1,700	440	320	1.4
	6/4/68	2,700	900	280	3.2
7	5/28/68	31	1	12	0.1
	6/4/68	160	36	29	1.2
8	5/28/68	17	0	7	0.0
	6/4/68	90	11	25	0.4
9	5/28/68	5	1	2	0.5
	6/4/68	0	1	22	0.04
10	5/28/68	0	4	0	0.0
	6/4/68	20	3	3	1.0
11	5/28/68	0	0	3	0.0
	6/4/68	0	130	37	3.5
12	5/28/68	350	530	100	5.3
	6/4/68	1,300	800	1,600	0.5

FC = Fecal Coliform; FS = Fecal Streptococci

APPENDIX TABLE 6
WATER QUALITY ON JUNE 4, 1968
BUFFALO LAKE PROJECT

Sample Station & Depth	Date & Time	Air Temp. (°F)	Water Temp. (°F)	pH (units)	Conductivity (μmhos/cm)	Dissolved Oxygen (mg/l)
6 Surface	6/4/68 1615	-	77	-	-	12.9
7 Surface	6/4/68 1630	72	72	9.1	1550	10.0
8 Surface	6/4/68 1625	73	71	9.1	1550	7.7
9 Surface	6/4/68 1605	74	73	9.1	1600	8.1
10 Surface	6/4/68 1540	74	71	9.0	1600	8.2
11 Surface	6/4/68 1550	74	73	9.0	1525	9.0
12 Surface	6/4/68 1525	-	79	-	-	25.8

APPENDIX TABLE 7
PHASE II BACTERIOLOGICAL RESULTS
BUFFALO LAKE PROJECT

Sample Station	Date of Collection	Time of Collection	Total Coliform /100 ml	Fecal Coliform /100 ml	Fecal Streptococci /100 ml	FC/FS* Ratio
1	6/12/68	0915	2,500	190	270	0.7
1	6/13/68	1005	1,500	190	570	0.3
2	6/12/68	0950	1,500	550	1,600	0.3
2	6/13/68	0940	1,600	640	1,800	0.3
3	6/12/68	1020	780,000	80,000	10,000	8.0
3	6/13/68	1045	750,000	80,000	14,000	5.7
4	6/12/68	1030	19,000	2,800	3,900	0.7
4	6/13/68	1055	14,000	1,600	3,400	0.5
5	6/12/68	1045	14,000	2,700	720	3.7
5	6/13/68	1105	20,000	1,090	43,000	0.02
6	6/12/68	1120	1,400	780	870	0.9
6	6/12/68	1645	1,100	850	1,060	0.8
6	6/12/68	2030	1,300	690	970	0.7
6	6/13/68	0030	1,400	570	900	0.6
6	6/13/68	0445	1,300	450	940	0.5
6	6/13/68	0730	1,600	330	1,100	0.3
6	6/13/68	1130	1,200	490	1,000	0.5
6	6/14/68	1430	1,800	640	640	1.0
6	6/15/68	1715	1,200	660	360	1.8
6	6/16/68	1750	1,850	670	3,400	0.2
6	6/17/68	1425	1,570	800	660	1.2
7	6/12/68	1100	60	30	70	0.4
7	6/13/68	1143	180	40	110	0.4
7	6/14/68	1030	100	35	45	0.8
7	6/15/68	1000	35	10	12	0.8
7	6/16/68	1035	50	10	95	0.1
7	6/16/68	1440	60	25	35	0.7
7	6/17/68	0955	100	25	80	0.3
8	6/12/68	1015	40	10	25	0.4
8	6/12/68	1445	15	15	27	0.5
8	6/12/68	1805	50	17	40	0.4
8	6/12/68	2250	35	27	67	0.4
8	6/13/68	0300	70	25	57	0.4

* FC = Fecal Coliform; FS = Fecal Streptococci

APPENDIX TABLE 7 (Continued)
PHASE II BACTERIOLOGICAL RESULTS
BUFFALO LAKE PROJECT

Sample Station	Date of Collection	Time of Collection	Total Coliform /100 ml	Fecal Coliform /100 ml	Fecal Streptococci /100 ml	FC/FS* Ratio
8	6/13/68	0630	70	20	90	0.2
8	6/13/68	1135	60	10	52	0.2
8	6/14/68	1020	50	5	10	0.5
8	6/15/68	1015	35	10	20	0.2
8	6/15/68	1445	40	< 5	15	< 0.3
8	6/15/68	1815	20	< 5	10	< 0.5
8	6/16/68	1050	35	5	65	0.08
8	6/16/68	1450	25	< 5	12	< 0.4
8	6/17/68	1000	110	15	40	0.4
8-A	6/15/68	1040	100	7	10	0.7
8-A	6/15/68	1500	20	15	20	0.7
8-A	6/15/68	1830	15	5	10	0.5
8-A	6/16/68	1110	20	< 5	5	< 1.0
8-A	6/16/68	1455	5	< 5	10	< 0.5
8-A	6/17/68	1020	35	5	80	0.1
9	6/12/68	1200	10	5	15	0.3
9	6/13/68	1210	15	< 5	10	< 0.5
9	6/14/68	1110	< 5	< 5	< 5	-
9	6/15/68	1050	20	5	< 5	> 1.0
9	6/16/68	1120	10	< 5	10	< 0.5
9	6/17/68	1030	5	< 5	10	< 0.5
10	6/12/68	1245	5	< 5	10	< 0.5
10	6/13/68	1240	< 5	< 5	< 5	-
10	6/14/68	1140	< 5	< 5	12	< 0.4
10	6/15/68	1130	< 5	5	35	0.1
10	6/16/68	1155	< 5	< 5	10	< 0.5
10	6/17/68	1105	90	75	140	0.5
11	6/12/68	1220	10	10	5	2.0
11	6/13/68	1230	40	5	10	0.5
11	6/14/68	1125	20	< 5	10	< 0.5
11	6/15/68	1115	< 5	< 5	< 5	-
11	6/16/68	1145	< 5	< 5	5	< 1.0
11	6/17/68	1050	< 5	< 5	20	< 0.3
12	6/12/68	1725	6,500	4,200	13,300	0.3
12	6/13/68	1515	600	20	520	0.04

APPENDIX TABLE 7 (Continued)
PHASE II BACTERIOLOGICAL RESULTS
BUFFALO LAKE PROJECT

Sample Station	Date of Collection	Time of Collection	Total Coliform /100 ml	Fecal Coliform /100 ml	Fecal Streptococci /100 ml	FC/FS* Ratio
12	6/14/68	1550	300	30	270	0.1
12	6/15/68	1605	100	10	160	0.06
12	6/16/68	1630	1,500	60	185	0.3
12	6/17/68	1320	220	180	310	0.6
7-M △	6/14/68	1030	< 3,300	< 3,300	6,600	-
7-M	6/15/68	1000	< 3,300	< 3,300	< 3,300	-
8-M	6/14/68	1020	< 3,300	< 3,300	< 3,300	-
8-M	6/15/68	1015	< 3,300	< 3,300	< 3,300	-
8-M	6/16/68	1050	< 3,300	< 3,300	< 3,300	-
8-M	6/17/68	1000	< 3,300	< 3,300	< 3,300	-
9-M	6/14/68	1110	< 3,300	< 3,300	8,300	-
9-M	6/15/68	1050	< 3,300	< 3,300	< 3,300	-
9-M	6/16/68	1120	< 3,300	< 3,300	< 3,300	-
9-M	6/17/68	1030	< 3,300	< 3,300	< 3,300	-
10-M	6/14/68	1140	< 3,300	< 3,300	< 3,300	-
10-M	6/15/68	1130	< 3,300	< 3,300	< 3,300	-
11-M	6/14/68	1125	< 3,300	< 3,300	< 3,300	-
11-M	6/15/68	1115	< 3,300	< 3,300	< 3,300	-
11-M	6/16/68	1145	< 3,300	< 3,300	< 3,300	-
11-M	6/17/68	1050	< 3,300	< 3,300	< 3,300	-

△ = Bottom Mud Sample

APPENDIX TABLE 8
WATER QUALITY DURING 24-HOUR SAMPLING
BUFFALO LAKE PROJECT

Sample Station	Date	Time	Air Temp (°F)	Water Temp (°F)	pH (units)	Conductivity µmhos/cm	Dissolved Oxygen mg/l
8	6/12/68	1015	79	70	9.2	1550	5.6
8	6/12/68	1455	84	72	7.8	1550	8.2
8	6/12/68	1810	82	72	8.9	1550	8.4
8	6/12/68	2250	68	70	10.7	1550	7.2
8	6/13/68	0300	67	70	9.6	1550	6.4
8	6/13/68	0630	65	68	9.1	1550	6.4
8	6/13/68	1135	79	70	8.9	1570	6.8
6	6/12/68	1120		72			4.0
6	6/12/68	1645	86	79	8.0	580	6.4
6	6/12/68	2030	70	70	8.0	600	5.2
6	6/13/68	0030	69	65	9.6	580	4.8
6	6/13/68	0445	64	64	9.6	600	4.4
6	6/13/68	0715	69	64	7.9	610	4.0
6	6/13/68	1130	82	72	7.8		5.5

APPENDIX TABLE 9
RESULTS OF PESTICIDE SAMPLING DURING RUNOFF
BUFFALO LAKE PROJECT

Pesticide	Water Grab Samples Taken 7/12/68 Sample Stations W	6	11
Dieldrin (ppb)	< 0.05	< 0.05	< 0.05
Malathion (ppb)	< 0.10	< 0.10	< 0.10
Parathion (ppb)	< 0.10	< 0.10	< 0.10
DDT (ppb)	< 0.10	< 0.10	< 0.10
2, 4-D (ppb)	< 0.50	< 0.50	< 0.50
Di-Syston (ppb)	< 0.10	< 0.10	< 0.10
Methyl Parathion (ppb)	< 0.10	< 0.10	< 0.10

ppb - parts per billion

Note: Values given represent the limits of detection.

APPENDIX TABLE 10
PHASE III BACTERIOLOGICAL RESULTS
BUFFALO LAKE PROJECT

Sampling Station	Date of Collection	Time of Collection	Total Coliform /100 ml	Fecal Coliform /100 ml	Fecal Streptococci /100 ml	FC/FS* Ratio
1	7/8/68	1555	500	170	280	0.6
	7/9/68	0955	430	200	135	1.5
	7/10/68	1045	3,000	1,060	1,150	0.9
	7/12/68	0735	5,600	890	2,500	0.4
	7/12/68	1320	4,400	670	2,000	0.3
	7/13/68	1320	4,400	1,400	4,000	0.4
	7/14/68	1200	600	220	310	0.7
	7/15/68	1005	1,450	240	420	0.6
1-B	7/8/68	1610	3,100	2,500	2,300	1.1
	7/9/68	1020	3,000	1,740	1,700	1.0
	7/10/68	1100	5,600	2,400	4,600	0.5
	7/12/68	0715	14,000	6,800	11,000	0.6
	7/12/68	1345	16,000	9,600	5,400	1.8
	7/13/68	1300	290,000	7,900	33,000	0.2
	7/14/68	1220	< 1,000	2,700	5,700	0.5
	7/15/68	1030	5,800	1,000	5,300	0.2
2	7/8/68	1630	900	730	720	1.0
	7/9/68	1030	1,600	760	1,220	0.6
	7/10/68	1110	520	190	280	0.7
	7/12/68	0700	7,100	390	2,700	0.1
	7/12/68	1400	1,800	120	260	0.5
	7/13/68	1250	51,000	8,300	117,000	0.07
	7/14/68	1230	110,000	1,900	4,100	0.5
	7/15/68	1045	24,000	980	1,600	0.6
2-B	7/8/68	1645	57,000	8,000	8,500	0.9
	7/9/68	1045	28,000	5,600	8,300	0.7
	7/10/68	1130	6,300	1,060	1,460	0.7
	7/12/68	0630	37,000	4,300	18,000	0.2
	7/12/68	1510	74,000	5,700	6,600	0.9
	7/13/68	1225	72,000	6,000	61,000	0.1
3	7/8/68	1730	5,700,000	1,390,000	74,000	18.8
	7/9/68	1100	1,000,000	210,000	15,000	14.0
	7/10/68	1145	6,500,000	660,000	63,000	10.5
	7/12/68	0105	12,400,000	6,100,000	300,000	20.3
	7/12/68	1525	23,000,000	6,100,000	330,000	18.5
	7/13/68	1140	6,100,000	1,000,000	130,000	7.7
	7/14/68	1305	22,000,000	2,900,000	290,000	10.0
	7/15/68	1105	12,000,000	2,400,000	150,000	16.0

* FC = Fecal Coliform: FS = Fecal Streptococci

APPENDIX TABLE 10 (Continued)
PHASE II: BACTERIOLOGICAL RESULTS
BUFFALO LAKE PROJECT

Sampling Station	Date of Collection	Time of Collection	Total Coliform /100 ml	Fecal Coliform /100 ml	Fecal Streptococci /100 ml	FC/FS Ratio
4	7/8/68	1740	270,000	36,000	148,000	0.2
	7/9/68	1110	38,000	9,700	34,000	0.3
	7/10/68	1155	190,000	14,000	170,000	0.08
	7/12/68	0055	1,700,000	Undetermined	10,800,000	-
	7/12/68	1540	8,500,000	900,000	54,000	16.7
	7/13/68	1210	19,000,000	1,400,000	170,000	8.2
	7/14/68	1315	7,500,000	900,000	2,100,000	0.4
	7/15/68	1115	5,400,000	1,200,000	100,000	12.0
5	7/8/68	1755	130,000	57,000	196,000	0.3
	7/9/68	1120	90,000	29,000	204,000	0.1
	7/10/68	1205	63,000	5,300	56,000	0.09
	7/12/68	0450	240,000	200,000	2,400,000	0.08
	7/12/68	1550	200,000	130,000	270,000	0.8
	7/13/68	1055	4,700,000	550,000	380,000	1.4
	7/14/68	1325	4,600,000	550,000	90,000	6.1
	7/15/68	1130	810,000	170,000	60,000	2.8
5-B	7/9/68	1830	15,000	5,000	46,000	0.1
	7/10/68	1220	16,000	3,600	25,000	0.1
	7/12/68	0535	150,000	49,000	290,000	0.2
	7/12/68	1615	910,000	800,000	2,200,000	0.4
	7/13/68	1105	1,700,000	240,000	140,000	1.7
5-C	7/12/68	0510	88,000	31,000	260,000	0.1
5-D	7/9/68	1910	> 100,000	4,500,000	250,000	18.0
	7/10/68	1245	10,000,000	6,100,000	76,000,000	0.08
	7/12/68	1710	1,000,000	850,000	6,600,000	0.1
6	7/8/68	1850	630,000	480,000	870,000	0.6
	7/9/68	1800	24,000	19,000	56,000	0.3
	7/10/68	1435	21,000	14,000	73,000	0.2
	7/11/68	1635	25,000	8,500	44,000	0.2
	7/12/68	1035	12,000	4,000	40,000	0.1
	7/12/68	1740	84,000	13,000	18,000	0.7
	7/13/68	1545	16,000	2,300	5,000	0.5
	7/14/68	1350	5,000	1,600	2,700	0.6
	7/15/68	1155	4,700	1,900	4,000	0.5
7	7/9/68	1315	100	20	65	0.3
	7/10/68	1535	40	20	100	0.2
	7/11/68	1405	100	5	30	0.2
	7/12/68	1555	250	90	175	0.5

APPENDIX TABLE 10 (Continued)
PHASE III BACTERIOLOGICAL RESULTS
BUFFALO LAKE PROJECT

Sampling Station	Date of Collection	Time of Collection	Total Coliform /100 ml	Fecal Coliform /100 ml	Fecal Streptococci /100 ml	FC/FS Ratio
7	7/13/68	1100	350	75	380	0.2
	7/14/68	1130	200	50	90	0.6
	7/15/68	1045	1,000	20	90	0.2
8	7/9/68	1330	135	10	40	0.3
	7/10/68	1545	60	10	22	0.5
	7/11/68	1410	15	12	30	0.4
	7/12/68	1600	80	10	60	0.2
	7/13/68	1115	280	50	200	0.3
	7/14/68	1140	70	10	45	0.2
	7/15/68	1050	1,700	< 5	25	< 0.2
8-A	7/9/68	1335	80	25	10	2.5
	7/10/68	1550	10	5	20	0.3
	7/11/68	1430	35	5	30	0.2
	7/12/68	1650	15	5	10	0.5
	7/13/68	1125	90	30	85	0.4
	7/14/68	1145	30	< 5	32	< 0.2
	7/15/68	1055	2,400	< 5	7	< 0.7
8-B	7/11/68	1435	15	5	10	0.5
	7/12/68	1610	100	5	15	0.3
9	7/9/68	1355	50	20	65	0.3
	7/10/68	1610	20	115	550	0.2
	7/11/68	1445	20	45	105	0.4
	7/12/68	1615	400	200	225	0.9
	7/13/68	1135	60	20	150	0.1
	7/14/68	1150	< 10	27	135	0.2
	7/15/68	1110	2,300	< 5	75	< 0.07
9-A	7/10/68	1645	2,200	1,000	5,800	0.2
	7/11/68	1450	420	360	1,900	0.2
	7/12/68	1620	220	200	630	0.3
10	7/9/68	1430	46,000	26,000	308,000	0.08
	7/10/68	1630	19,000	8,500	61,000	0.1
	7/11/68	1500	5,300	3,900	45,000	0.09
	7/12/68	1635	3,600	3,200	43,000	0.07
	7/13/68	1200	5,500	2,300	42,000	0.05
	7/14/68	1210	1,500	1,000	13,000	0.08
	7/15/68	1130	1,900	1,000	25,000	0.04

APPENDIX TABLE 10 (Continued)
PHASE III BACTERIOLOGICAL RESULTS
BUFFALO LAKE PROJECT

Sampling Station	Date of Collection	Time of Collection	Total Coliform /100 ml	Fecal Coliform /100 ml	Fecal Streptococci /100 ml	FC/FS Ratio
11	7/9/68	1415	41,000	29,000	520,000	0.06
	7/10/68	1620	10,000	4,800	75,000	0.06
	7/11/68	1455	1,200	610	9,700	0.06
	7/12/68	1630	2,500	500	2,000	0.3
	7/13/68	1150	3,400	1,300	24,000	0.05
	7/14/68	1200	1,400	660	12,000	0.06
	7/15/68	1125	2,500	670	21,000	0.03
12	7/8/68	2030	242,000	209,000	860,000	0.2
	7/9/68	1615	64,000	48,000	280,000	0.2
	7/10/68	1805	37,000	14,000	91,000	0.2
	7/11/68	1600	41,000	28,000	88,000	0.3
	7/12/68	1800	38,000	21,000	45,000	0.5
	7/13/68	1930	45,000	11,000	41,000	0.3
	7/14/68	1250	79,000	27,000	87,000	0.3
	7/15/68	1210	56,000	12,000	46,000	0.3
13	7/8/68	1700	118,000	71,000	86,000	0.8
	7/12/68	0820	74,000	60,000	90,000	0.7
	7/12/68	1640	66,000	29,000	79,000	0.4
	7/13/68	1125	100,000	22,000	120,000	0.2
A	7/12/68	0430	3,600,000	2,900,000	56,000,000	0.05
	7/13/68	1005	9,000,000	6,300,000	74,000,000	0.09
B	7/12/68	0415	450,000	92,000	310,000	0.3
	7/13/68	0955	240,000	56,000	110,000	0.5
C	7/12/68	0340	260,000	310,000	4,800,000	0.06
	7/13/68	0940	5,400,000	3,100,000	47,000,000	0.07
D	7/12/68	0320	80,000	26,000	360,000	0.07
	7/13/68	0925	61,000	< 1,000	58,000	< 0.02
W	7/8/68	1330	126,000	7,100	11,700	0.6
	7/12/68	0735	13,000	2,000	< 10,000	> 0.2
	7/12/68	1250	17,000	1,000	20,000	0.05
W-1	7/10/68	1020	620,000	240,000	620,000	0.4
X	7/8/68	1305	207,000	500,000	4,400,000	0.1
	7/9/68	0925	300,000	170,000	1,510,000	0.1
	7/10/68	1010	89,000	37,000	460,000	0.08

APPENDIX TABLE 10 (Continued)
PHASE III BACTERIOLOGICAL RESULTS
BUFFALO LAKE PROJECT

Sampling Station	Date of Collection	Time of Collection	Total Coliform /100 ml	Fecal Coliform /100 ml	Fecal Streptococci /100 ml	FC/FS Ratio
X	7/12/68	0710	1,800,000	710,000	8,600,000	0.08
	7/12/68	1230	520,000	130,000	1,060,000	0.1
Y-1	7/8/68	1250	153,000	3,400	33,000	0.1
	7/9/68	0905	40,000	5,100	12,000	0.4
	7/12/68	0650	260,000	6,000	59,000	0.1
	7/12/68	1215	250,000	3,200	26,000	0.1
Z	7/8/68	1215	390,000	17,000	56,000	0.3
	7/9/68	0940	650,000	3,500	22,000	0.2
	7/10/68	0950	57,000	2,800	8,000	0.4
	7/12/68	0615	14,000	3,000	2,000	1.5
	7/12/68	1125	53,000	11,000	8,000	1.4